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Koolhaas, J.M.; Mora, F.; Phillips, A.G.

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BRIEF COMMUNICATION

Effects of Food and Water Deprivation on Self-Stimulation of the Medial and Sulcal Prefrontal Cortex and Caudate Putamen in the Rat

J. M. KOOLHAAS,¹ F. MORA AND A. G. PHILLIPS

Department of Experimental Psychology, University of Oxford, England

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KOOLHAAS, J. M., F. MORA AND A. G. PHILLIPS. *Effects of food and water deprivation on self-stimulation of the medial and sulcal prefrontal cortex and caudate putamen in the rat.* *PHYSIOL. BEHAV.* 18(2) 329-331, 1977. – Self-stimulation rates from electrodes, implanted in the terminal areas of the mesocortical and nigrostriatal dopaminergic systems, were measured during food or water deprivation. A significant increase of sulcal prefrontal cortex self-stimulation was observed after 24 and 48 hr of food deprivation. Self-stimulation of the medial prefrontal cortex and the neostriatum was unaffected. Water deprivation had no effect on any of the structures tested. This suggests that similar effects found in the hypothalamus by other authors may be due to activation of the mesocortical system.

Self-stimulation Deprivation Dopaminergic systems

THE lateral hypothalamus is the only brain area from which a clear relationship between self-stimulation and feeding behaviour has been demonstrated. Olds [13] reported a strong increase in the self-stimulation rate of the lateral hypothalamus during food deprivation, whereas Hoebel [6] conversely demonstrated a decrease as a result of both long- and short-term satiety factors.

Recent research on feeding behaviour has focussed on the areas of origin and termination of the two dopaminergic fiber systems passing through the lateral hypothalamus. Lesions in the nigrostriatal system cause deficits in feeding behaviour, which are quite similar to those seen after hypothalamic lesions [10,19]. Also, lesions in the prefrontal cortex (the terminal area of the mesocortical system) affect feeding behaviour, producing finickiness and hypophagia, respectively, in medial and sulcal prefrontal cortex [7]. Similar results were obtained after lesions in the orbitofrontal cortex in the rhesus monkey [2], an area which may be homologous to the sulcal prefrontal cortex in the rat [9].

These ascending dopamine systems have also been implicated in brain stimulation reward. Self-stimulation has been reported from the region of dopamine cell bodies in the ventral tegmentum [4,17] and from the terminal areas of the nigrostriatal and mesocortical systems [15, 16, 18]. Given the possible involvement of these dopamine systems

in both feeding and self-stimulation, it is tempting to consider that the effects of food deprivation on hypothalamic self-stimulation may have been due to stimulation of dopaminergic fibres of passage. As a direct test of this hypothesis, rats were prepared with electrodes chronically implanted in the terminal areas of both the mesocortical and nigrostriatal systems, and the effects of food and water deprivation on self-stimulation at these structures were investigated.

METHOD

Animals and Surgery

Twelve male Sprague-Dawley rats, weighing 350 g at the time of surgery, were implanted with three monopolar stainless-steel electrodes (00 ga), bare only at the cross-section of the tip. The electrodes were aimed at the sulcal prefrontal cortex (coordinates: A 2.5, L 3.0, V 4.0), the medial prefrontal cortex (coordinates: A 2.5, L 0.8, V 2.0), and the caudate nucleus (coordinates: A 1.5, L 3.0, V 4.5). The coordinates were derived from the stereotaxic atlas of König and Klippel [7], using bregma as a reference point.

Procedure

All animals were housed in individual cages (30 × 50 × 30 cm) with a wiremesh floor, to prevent eating of faeces

¹ Requests for reprints should be sent to J. M. Koolhaas, Department of Zoology, University of Groningen, Haren, Holland.

during food deprivation. A reversed day-night schedule was used (12 hr light, 12 hr dark) and all experiments were performed in the second and third hour of the dark cycle.

The animals were tested for self-stimulation in a Plexiglas box (26 × 16 × 38 cm). Each time the animal pressed a bar at one end of the box, it received a train of 0.1 msec electrical pulses at a frequency of 100 Hz for 0.1 sec. The current intensity of each site was chosen such that a reliable pressing was obtained without interference of seizures. The current intensities were held constant for the duration of the experiment.

The self-stimulation rate on the 3 sites was determined in daily sessions of 15 min in the same order (1 caudate, 2 sulcal, 3 medial prefrontal cortex) and there was a 2 min change-over period between each site.

After 2 weeks of testing under ad lib food and water, the animals were food-deprived at the end or at the beginning of the dark period and tested, respectively, 12, 24, and 48 hr later. The experiment was repeated after 3 days under ad lib food and water. The same procedure was followed with 12 and 24 hr water-deprivation.

After completion of all experiments the animals were sacrificed and perfused with 0.9% saline followed by 10% Formalin. Frozen sections of 25 microns were cut and stained with cresyl violet.

RESULTS

Histology

Coronal sections of the rat brain, indicating the electrode tip locations of the experimental animals are presented in Fig. 1. All caudate putamen and medial prefrontal cortex electrodes were in the right position. Two sulcal prefrontal cortex electrodes were rather dorsal, but these placements did not differ behaviourally from the other electrodes in this area.

Self-stimulation

After the initial training period of about 4 weeks, 7 animals, which pressed reliably on all 3 electrodes, were

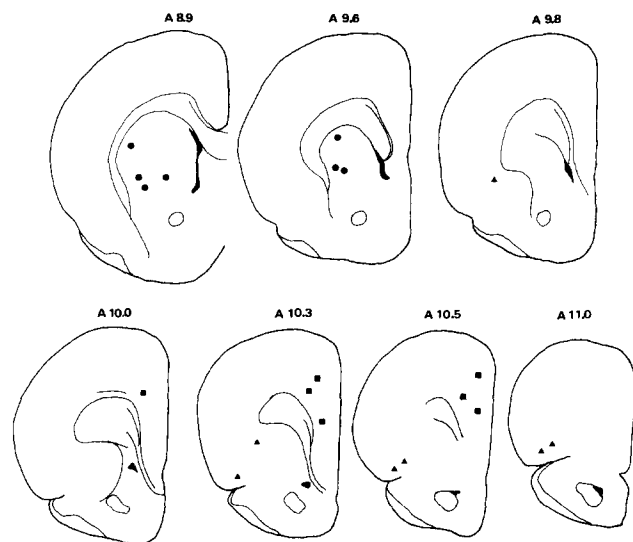


FIG. 1. Sections from König and Klippel (1963) showing the electrode tip locations. ● = caudate-putamen, ■ = medial prefrontal cortex, ▲ = sulcal prefrontal cortex.

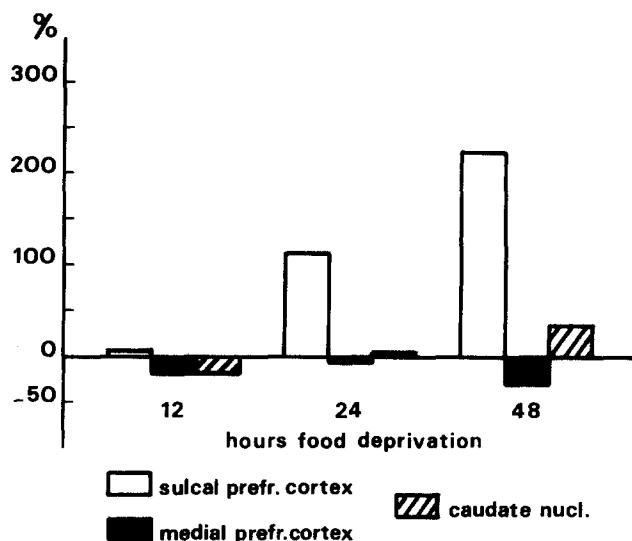


FIG. 2. Mean percentage deviation from baseline self-stimulation rate during different periods of food deprivation.

selected. Mean baseline rates, determined in the next period of 2 weeks were as follows: Sulcal prefrontal cortex - 131 (± 33); Medial prefrontal cortex - 704 (± 81); Caudate putamen - 185 (± 24). Attempts to get an equal rate of self-stimulation on all 3 sites failed because the animals either stopped pressing at lower current intensities or got seizures at higher intensities. Occasionally, seizures were observed, but data obtained after a seizure were not included for further analysis.

Figure 2 shows the effect of different periods of food deprivation on the self-stimulation rate of each of the 3 electrode sites, expressed as the mean percentage deviation from baseline level.

Twenty-four and 48 hr of food deprivation caused a significant ($p < 0.05$) increase in self-stimulation rate of the sulcal prefrontal cortex, but did not affect self-stimulation of the medial prefrontal cortex and neostriatum. Twelve hours of food-deprivation did not affect the self-stimulation rate of any of the 3 electrode sites.

Figure 3 shows the percentage deviation from baseline self-stimulation rate during 12 and 24 hr of water deprivation. Self-stimulation was not significantly affected at any of the electrode sites by this treatment.

DISCUSSION

The results of the present experiment show a facilitatory effect of food deprivation on self-stimulation of the sulcal prefrontal cortex. This facilitatory effect cannot be attributed to an increase in general activity induced by starvation because self-stimulation of sites in medial prefrontal cortex and caudate-putamen in the same animals, tested in the same session, was unaffected. Further evidence that the observed effects are best attributed to food deprivation per se, comes from the fact that a similar period of water-deprivation produced no significant change at any of the electrode loci. However, important differences in baseline rate were observed between the different test sites. The insensitivity of medial prefrontal cortex and caudate-putamen to food-deprivation could therefore be due to ceiling effects. Since a subsequent experiment performed with the same animals showed a specific increase in

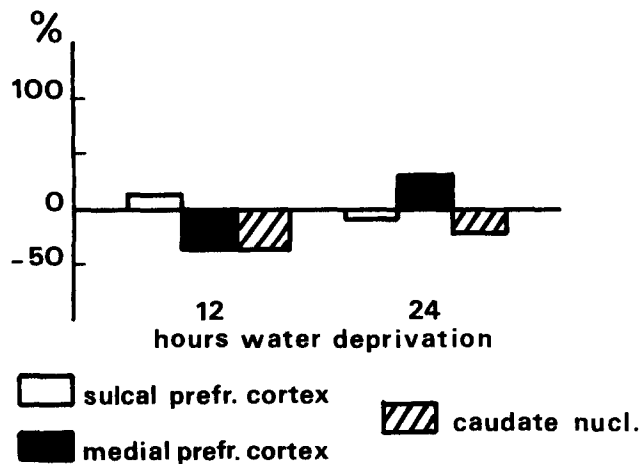


FIG. 3. Mean percentage deviation from baseline self-stimulation rate during different periods of water deprivation.

self-stimulation rate of caudate-putamen in the majority of the animals (48), such an effect is unlikely for that structure. Ceiling effects cannot be excluded, however, for the prefrontal cortex, although our results in this structure are consistent with those mentioned by other authors [3,5].

Our main conclusion, therefore, is that self-stimulation of the sulcal prefrontal cortex is influenced in some way by factors controlling food intake. Unpublished observations

(Mora, Phillips and Rolls) indicate that the same phenomenon can be observed on self-stimulation sites in the orbitofrontal cortex of the rhesus monkey, an area which is thought to be homologous to the sulcal prefrontal cortex of the rat [9].

Evidence for a dopaminergic substrate of self-stimulation in the present prefrontal cortical sites comes from subsequent experiments in which the dopamine-receptor agonist apomorphine was shown to produce a dose-related inhibition of self-stimulation at both medial and sulcal sites [12].

Given the fact that the dopaminergic mesocortical pathway projects through the hypothalamus and the fact that previous experiments showed similar effects of food and water deprivation at sites in the lateral hypothalamus [1, 11, 13], there is a strong possibility that the effects as found in the hypothalamus are due to activation of this pathway. It would be of particular interest therefore to find out if there is any difference in the nature of the factors affecting self-stimulation in hypothalamus and sulcal prefrontal cortex.

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